XXI. *On the dispersive power of the atmosphere, and its effect on astronomical observations. By* Stephen Lee, *Clerk and Librarian to the Royal Society. Communicated by* W. H. Wollaston, *M. D. Sec. R. S.*

Read June 15, 1815.

NOTWITHSTANDING the pains which astronomers have taken to determine accurately the refraction of mixed light, nothing, I believe, has ever been done towards ascertaining the dispersive power of common air, or comparative degree of refrangibility of the differently coloured rays in their passage through our atmosphere.

The importance of such an inquiry, however, must be obvious to every one who duly considers the effect which the different degrees of refrangibility of the variously coloured lights must necessarily produce in the apparent situations of differently coloured objects. Stars of different colours must be differently refracted, and the apparent altitude of the sun must vary according to the colour of the dark glass through which he is viewed.

Perhaps this cause alone is sufficient to explain the disagreement which is found to exist between the latitude of a place deduced from observations of circumpolar stars, and that deduced from observations of the sun during the solstices, which has so long occupied the attention of astronomers, and has never yet been satisfactorily accounted for.*

* Vide Mr. PIAZZI's Memoir on the Obliquity of the Ecliptic, in the Memoirs of the Società Italiana, Vol. XI.

The dispersive power of the atmosphere will also show why Aldebaran and the red stars are sometimes seen projected on the moon's disk in occultations by that planet, especially when the immersion or emersion happens to be near her upper limb. For the light of the moon being white, is more refracted than that of the star, and consequently her limb more elevated, which would occasion the star to appear within her disk a few seconds before or after contact.†

The great disagreement which is found to exist in the declination of several of the fixed stars, as given by different observers, may probably be traced to the same cause, stars being more or less refracted according to the predominant colour of which their light is composed.

That the fixed stars differ from each other in respect to the composition of their light, must be obvious to any one who will only take the trouble of comparing them on a fine night. They present a striking variety of colour even to the naked eye. But this difference becomes still more perceptible when they are viewed through a prism properly adapted to the eye-piece of a reflecting telescope.

A star viewed in this manner is converted into a prismatic spectrum. Sirius and the *brilliant* white stars exhibit a large brush of beautiful violet, and the most refrangible colours in great abundance. Aldebaran, α Orionis, and the red stars show only a small proportion of those colours, whilst the dull white stars exhibit a great quantity of intense green light.

† Vide Philosophical Transactions, Vol. LXXXIV. p. 345. Histoire Céleste Françoise, Tome I. p. 393, 403, 413, 425, 428, 467, and Connoissance des Temps for 1817.

The planets also differ much from each other in this respect. The moon, Venus, and Jupiter, seem to possess every colour; but the green is very pale in all of them. Mercury and Mars appear deficient in the middle and most refrangible rays, whilst the light of Saturn seems to be composed principally of the mean rays with a very small proportion of the extreme colours of the prism.*

The different refrangibility of the differently coloured rays is very visible in stars near the horizon. If viewed on a fine night with a power of 200 and upwards, they appear expanded into a prismatic spectrum. Sirius, when within a few degrees of the horizon, presents a most beautiful object.

Having remarked the very oblong figure which the spectrum assumes when near the horizon, and found from repeated observations of different stars that the separation of light begins to be visible as high as 40° or 50° of altitude, I was led to believe that the dispersive power of the atmosphere must be sufficient, in many cases, to produce considerable effect on astronomical observations; and, consequently, to suppose that it would be desirable to ascertain, if possible, the exact degree of separation of the several rays.†

With this view, therefore, I began a series of observations;

* Query. May not this circumstance explain why Saturn, though less brilliant, bears magnifying better than Jupiter and Venus?

† Dr. HERSCHEL, in a note to his Paper on Double Stars, published in the seventy-fifth volume of the Philosophical Transactions, says that the prismatic power of the atmosphere is very visible in low stars; and very justly observes that this power ought not to be overlooked in delicate and low observations: he gives the measure of two diameters of ε Sagittarii, which seem to indicate that the refraction of the extreme rays is about $\frac{1}{94}$ ±, the mean refraction. I think it due to that great astronomer to mention the circumstance, though it was totally unknown to me till long after I had completed my observations on Mars.

the result of which, and the manner of conducting them, I shall now take the liberty of laying before the Society.

The first instrument employed for the purpose with any degree of satisfaction, was the two feet reflector made by Mr. SHORT, and which belongs to the Royal Society. In the compound focus of the eye piece of this telescope, I fixed *horizontally* a narrow slip of ivory. With the instrument thus prepared, I observed Capella, and other low stars near the meridian. By carefully noticing the intervals of time between the first contact and total immersion, and between the first appearance and complete emersion of the star from behind the slip of ivory, I obtained data from which it was easy to calculate its vertical breadth, which, compared by estimation with its horizontal breadth, gave the separation of the extreme rays of light.

It was impossible, however, to remain long satisfied with such coarse measures, and not finding it convenient to go to much expense on this account, I applied to my friend Mr. RENNIE for the loan of his seven feet reflector made by Dr. HERSCHEL, to which I adapted a very excellent wire micrometer made by Mr. TROUGHTON; and thus, by the kind assistance of my friends, I obtained instruments capable of measuring small angles to the fraction of a second of space.

With this apparatus I repeatedly measured the diameter of Mars during his opposition in 1813. The Society's apartments being well situated for the purpose, I observed the planet as soon as he became visible over the buildings, until he attained his meridian altitude, which never exceeded 15°.

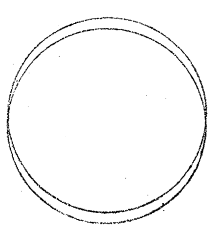
With a power of 170 and upwards, the disk of the planet appeared much elongated, especially when near the horizon; the upper limb was of a fine blue, the lower limb of a deep red.

By carefully measuring the diameter of Mars and the breadth of the coloured edges, I endeavoured to ascertain, as exactly as possible, the degree of separation of the differently coloured images of the planet.

But after all it was no easy matter to measure the coloured edges exactly, for the light which was necessary to illuminate the wires, rendered the colours so very faint as to make it extremely difficult to distinguish their precise boundaries. For this reason, and because I wished to apply higher powers than could be used with the micrometer, I adopted the following method, which I found far more convenient, and is, I believe, quite as accurate.

I drew on a sheet of paper several figures of two equal circles cutting each other, placing the centres of the circles in the first figure $\frac{1}{10}$ of their radius from each other; in the second figure $\frac{2}{10}$; in the third $\frac{3}{10}$; and so on. The upper crescent of these figures I painted blue, the lower crescent red, and the part common to both circles of a reddish yellow, softening the colours into each other as they appeared in the planet. For I considered that, in fact, it was not a single image of Mars that was seen, but a number of differently coloured images, lying in the same direction, though lifted one above another, as represented in the annexed figures.

1



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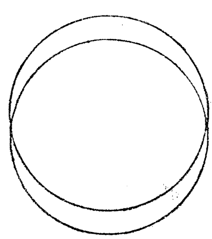

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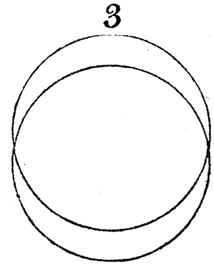

Having prepared a number of these drawings, I repeatedly compared them with the planet viewed through the telescope with different magnifying powers, carefully noting which figure he most resembled, and the time of observation.

This being done, it was easy to calculate the exact altitude from the time of observation, and to make a very near estimate of the separation of the images from the figure referred to, compared with the diameter of the planet found by the micrometer.

From a great number of observations on Mars, Venus, and the fixed stars, taken in all these different ways, I found the deviation of the extreme rays of light to be between $\frac{1}{60}$ and $\frac{1}{70}$ part of the total refraction.

It has already been observed, that the disagreement which is found to exist between the latitude of a place deduced from observations of circumpolar stars, and that from observations of the sun, may perhaps be traced to the use of dark glasses. But this will appear more evidently from a reference to the method employed by Dr. Bradley for determining the quantity of refraction, which method is very clearly described by Dr. Maskelyne in the seventy-seventh volume of the Philosophical Transactions. He says,

That Dr. Bradley got the height of the pole from observations of the circumpolar stars, and the height of the equator from observations of the sun at the two equinoxes; that he found these two altitudes together amounted to 89°, 58′, 3″, which being subtracted from 90°, leaves 1′, 57″, for the sum of the refractions at the pole and equator; and that of this quantity he assigned $45\frac{1}{2}''$ to the former, and $71\frac{1}{2}''$ to the latter.

But Dr. BRADLEY undoubtedly made use of dark glasses for observing the sun, probably smoked glasses, which would give him a pale orange coloured image, or one of less than mean refrangibility; consequently, the quantity of refraction as found by Dr. BRADLEY must be too small for white light.

This alone is sufficient to produce a small difference between the results of our observations of the sun and of the stars. I shall now mention two other circumstances which appear to me to have produced a still greater apparent disagreement.

The publication of the Nautical Almanac in 1767, led to the general use of HADLEY'S sextant. In the construction of this instrument, coloured glasses were indispensibly necessary; and the great convenience in the use of them over smoked glasses, soon occasioned the application of them to all other instruments. These glasses generally give a deep red image, or one of less refrangibility than smoked glass. The effect of this alteration, therefore, should have been, that arising from too great correction for refraction in every thing depending on observations of the sun.

The introduction of achromatic object glasses * produced an error of a different kind; and one which, in certain cases, tends to correct the other. In the single object glass telescope (and there were no others in BRADLEY'S time) the differently coloured images are formed at different focal distances, which, in a manner, compels the observer to adjust his instrument to the most intense light; that is to say, to the orange coloured † image; by this means the fainter colours,

* An achromatic object glass was first applied to the south quadrant at Greenwich in 1772, and to the north quadrant in 1789.

† Vide Newton's Optics, Book I. Part I. Prop. VII.

which occupy the greatest space in the spectrum,* are dissipated, and lost among the more powerful rays. In good achromatic telescopes the case is very different, for all the rays being collected by them into one point, every colour is seen in its proper place, so that the observer, in bisecting the spectrum, takes the altitude of the mean, or the upper extremity of the green image.

But if the upper extremity of the green image be taken in observations of circumpolar stars, a greater correction than Dr. BRADLEY'S ought to be applied, in order to get the true height of the pole.

It may not be amiss to observe here, that the observations of Mr. LALANDE at Paris, show a greater disagreement than those at Greenwich; and the observations of Mr. PIAZZI at Palermo, a still greater than those of Mr. LALANDE. This, I apprehend, must arise partly from the lesser elevation of the pole in those places, and partly from the fainter colours in the stellar spectra being more distinctly visible in the clear atmospheres of France and Italy than in England.

It should seem then, that in order to get a perfect knowledge of astronomical refraction, we ought to employ at least three different methods of investigation. 1st. By observations of the fixed stars during the night, when all the prismatic colours are visible. 2dly. By observations of the stars during the day, when none but the orange coloured rays are to be seen. And 3rdly, by observations of the sun with different coloured glasses. By these means we might hope to obtain such an accurate knowledge of atmospheric refraction as would enable us to form tables adapted to every possible circumstance.

* Vide Newton's Optics, Book I. Part II. Prop. III.

But I must not take up the time of the Society by any additional observations. It is in vain for me to pursue the subject any farther, in a situation so ill adapted to astronomical observations as Somerset Place; I shall therefore resign the task to those who are more favourably placed in this respect, and who possess instruments better calculated for an investigation which requires so much accuracy.